U.S. Fish and Wildlife Service Supplemental Upper Sacramento River Fall Chinook Salmon Carcass Survey

2011 Annual Report

Prepared by

Sarah Austing and Robert E. Null

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U.S. Fish & Wildlife Service
Red Bluff Fish & Wildlife Office
Red Bluff, California 96080

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Abstract
Central Valley fall Chinook salmon *Oncorhynchus tshawytscha* are an important species for commercial and recreational fishing, in addition to fulfilling an important role in the ecosystem. More than 32 million fall Chinook salmon are produced annually in California's Central Valley hatcheries, with a large percentage trucked to San Pablo Bay for release. This disruption of the natural outmigration process can lead to reduced imprinting by juveniles on their natal water source, which in turn can cause returning adult salmon to stray into non-natal streams, and can lead to negative impacts on natural spawning populations. To monitor returning adult hatchery-origin salmon, carcass surveys were performed weekly from mid-October through mid-December in 2011 on 48 miles of the upper Sacramento River in California's Central Valley. Coded-wire tags, biological, and genetic samples, and associated information were collected from recovered carcasses. We observed 148 carcasses during the survey period. The peak recovery of fresh carcasses occurred during the week of 13 November 2011. A total of 107 carcasses were sampled, and 74.8% of those were determined to be of hatchery origin. The highest concentration of carcasses was found between river miles 267 and 269, just downstream of where Battle Creek enters the Sacramento River. Sixty percent of the hatchery-origin salmon recovered within the survey area originated from the Coleman National Fish Hatchery, which is located on Battle Creek. Almost half of hatchery-origin recoveries were age-2 males. Future surveys would provide insight into annual variation of straying, spawn timing, spawning distribution, and proportion of hatchery-origin fall Chinook salmon in the Sacramento River, and assist in assessing potential negative impacts on native salmonid populations resulting from straying hatchery-origin salmon.

Introduction
Annually, more than 32 million fall Chinook salmon (FCS) are currently produced at five fish hatcheries in the Central Valley of California, including Coleman National Fish Hatchery (NFH), Feather River Fish Hatchery and the Feather River Hatchery Annex, Nimbus Fish Hatchery, Mokelumne River Fish Hatchery, and Merced River Fish Hatchery. Hatchery production of Central Valley FCS contributes substantially to sport and commercial fisheries in ocean and inland areas. Releasing large numbers of hatchery propagated salmonids, however, can result in negative effects to naturally-produced salmonids. For example, artificial propagation can pose genetic risks to natural salmonid populations which can affect locally adapted gene complexes, and have deleterious effects on fitness or survivorship (Hard *et al.* 1992; Cuenco *et al.* 1993; Waples 2007).

The potential for negative effects of hatchery salmonids to naturally-produced salmonids is reduced when hatchery salmon return as adults to their hatchery of origin, or "home", and is greater when hatchery salmon spawn in natural spawning areas, or "stray" (Quinn e*t al*. 1991; Williamson and May 2005). Naturally produced anadromous salmonids typically show a high level of fidelity to their natal spawning areas as a result of imprinting to environmental cues experienced by juvenile fishes throughout their rearing and downstream migration (Dittman and Quinn 1996). Imprinting is disrupted and straying is increased for hatchery salmon that are released at locations distant from the hatchery (Quinn 1993; Dittman and Quinn 1996). In recent years, many of the FCS produced at Central Valley hatcheries have been transported by truck to the downstream limit of the watersheds where they are released into San Pablo Bay. This practice has been shown to increase survival of juveniles by bypassing areas where high

mortality would otherwise occur during emigration, resulting in an increased abundance of salmon available for harvest (Kormos *et al.* 2012). At the same time, the practice of transporting juvenile salmon has also raised concerns about negative effects to naturally spawning salmon populations that may result from straying of hatchery-origin FCS.

Assessments of straying of hatchery-origin FCS in the Central Valley have been limited by low and inconsistent rates of marking or tagging of hatchery-origin salmon. Inadequate marking and tagging programs result in the inability to distinguish hatchery- and natural- origin FCS when they return to hatcheries and in natural spawning areas. Beginning in 2007, however, a representative portion of all hatchery production of FCS in the Central Valley has been marked with an adipose fin-clip and a coded-wire tag (CWT) has been inserted in the nasal cartilage. This program, called the Constant Fractional Marking (CFM) Program, targets 25% of FCS production releases to be marked and tagged on an annual basis (Buttars 2011). The overall objectives of the CFM program are:

1. To evaluate the contribution rates of hatchery salmon to Central Valley Chinook salmon populations;
2. To evaluate the Central Valley propagation program's genetic and ecological effects on natural Chinook salmon populations;
3. To estimate exploitation rates of hatchery and natural Central Valley Chinook salmon in ocean and inland fisheries;
4. To evaluate the success of restoration actions designed to increase natural production of Central Valley Chinook salmon;
5. To evaluate the relative impacts of water project operations on hatchery and naturally-produced Chinook salmon; and,
6. To evaluate the recovery of listed stocks of Chinook salmon (Buttars 2011).

To meet the objectives of the CFM program, rigorous field sampling programs are necessary to survey natural spawning areas. In 2011, the California's Central Valley Salmonid Escapement Project Work Team distributed a plan to provide a framework for long-term monitoring programs to estimate, in a statistically valid manner, the abundance and trends in escapement of adult Central Valley Chinook salmon at the watershed level (Bergman et al. 2012). The main objective of this Central Valley In-river Chinook Salmon Escapement Monitoring Plan is to improve estimates of the total number of Chinook salmon that "escape" fisheries and return to natural spawning areas (i.e., 'escapement') and estimate the percent of escapement that are of hatchery origin. Biological data (e.g., sex ratios, age, and length distributions) and data collected during surveys of natural spawning areas are also used to enhance understanding of the life history, status, and health of each stock, and be used to improve management. This monitoring plan calls for systematic surveys of important spawning areas of the Central Valley to collect biological data and recover CWTs (Bergman et al. 2012).

This study was undertaken to supplement existing monitoring programs of FCS escapement, which are conducted annually by the California Department of Fish and Wildlife (CDFW). The CDFW conducts annual carcass surveys in the uppermost 26 miles of the Sacramento River which are accessible to anadromous fishes, extending from Balls Ferry Boat Launch [river mile (RM) 276] to Keswick Dam (RM 302). This area is believed to encompass the primary

spawning areas for FCS in the upper Sacramento River (Killam 2012.). However, some FCS, including stray hatchery-origin salmon, spawn in lower reaches of the river which are not regularly surveyed. Additionally, the carcasses of male Chinook salmon are typically observed downstream of primary spawning areas (Killam 2009), and may therefore be underrepresented in surveys that don't cover the entire distribution of salmon carcasses.

The goal of this monitoring project is to collect CWTs, biological and genetic samples, and associated information from FCS in areas of the upper Sacramento River that are not surveyed, as recommended in the Central Valley In-river Chinook Salmon Escapement Monitoring Plan (Bergman *et al*. 2012). This information will be used to estimate the proportion of hatchery- and natural-origin FCS within the survey area, determine the hatchery of origin for hatchery produced salmon in the Sacramento River, estimate the sex ratio of FCS within the survey area, and determine the age class structure of hatchery-origin FCS.

Methods

Survey Area

The survey area covered approximately 48 miles of the Sacramento River immediately downstream of the area surveyed by the CDFW. The survey area was divided into 2 reaches; Reach 1 extended for 22 miles downstream from the Balls Ferry Boat Launch (RM 276) to China Rapids (RM 254) (Figure 1). Reach 2 extended from China Rapids (RM 254) to the boat launch at Mill Creek Park (RM 229), a distance of 26 miles (Figure 1).

River Conditions

River flow and water temperature data for the Sacramento River were obtained from the California Data Exchange Center. The data presented in this report relied on the water gage at Bend, California (BND) (RM 260), operated by U.S. Geological Survey (USGS) and California Department of Water Resources (DWR).

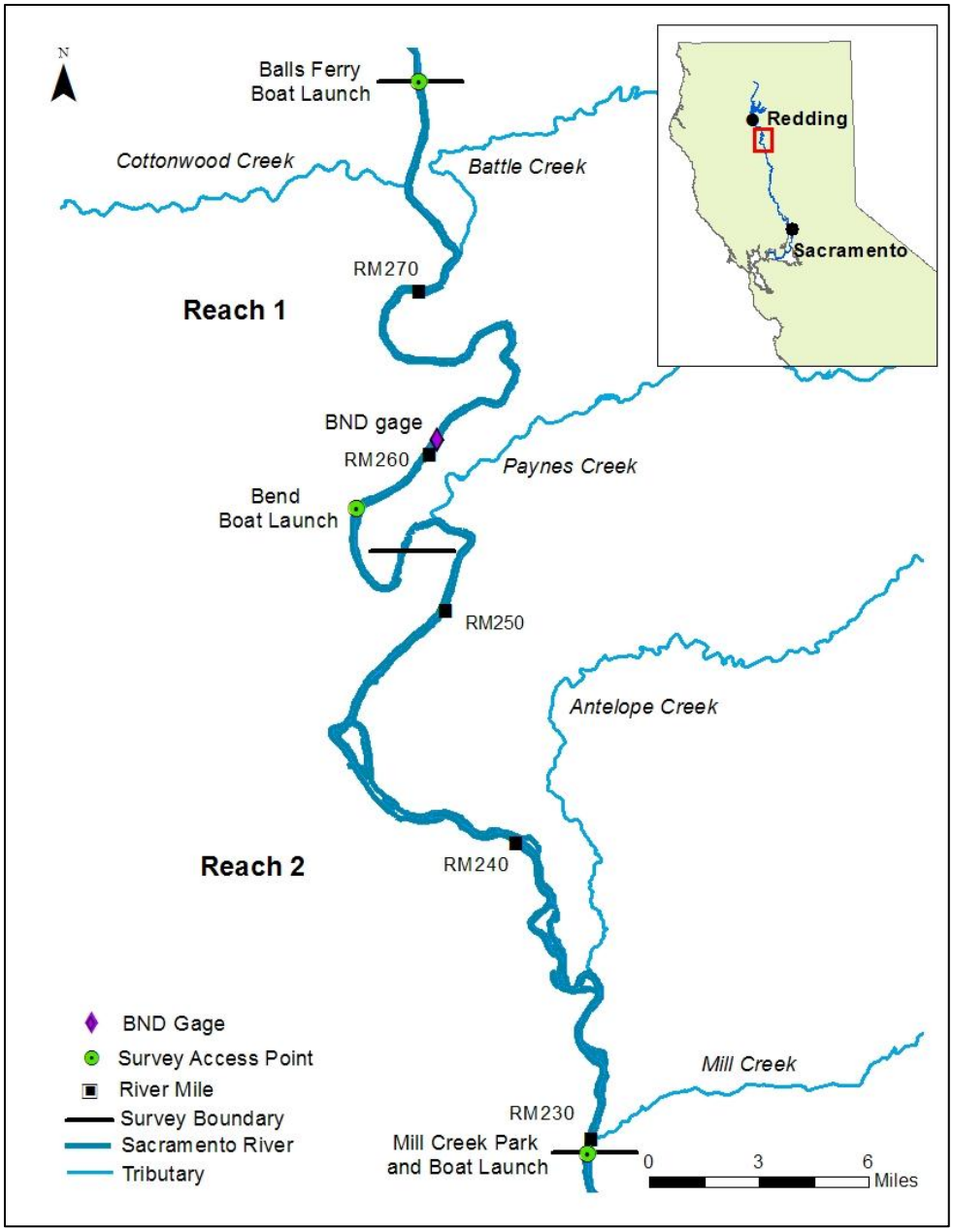


Figure 1. Fall Chinook salmon carcass survey area of the Sacramento River (RM 229- RM 276). Survey area is indicated in red on the California state map.

Sampling Protocol

Carcass surveys were conducted between 11 October 2011 and 20 December 2011, and encompassed the majority of the period of FCS spawning in the Sacramento River. The surveys began prior to the beginning of most FCS spawning and were terminated when the number of carcasses recovered was almost zero and most carcasses recovered were in an advanced state of decay, indicating that spawning activity had subsided. Both reaches were surveyed weekly, beginning with the reach farthest downstream and moving upstream on the following day.

The survey was conducted with one jet boat and two observers. The survey was performed by driving upstream from the launch site on one side of the river to the boundary of the reach and then continuing on the opposite bank downstream to the launch site. Sampling gear included a 5-meter gig pole, data sheet, global positioning system (GPS) device, specimen vials, specimen knives, and a machete.

Carcasses were recovered using a 5-meter wooden pole with a five pronged gig attached to one end that was used to spear the carcass. The physical condition of each carcass was estimated as "fresh" or "non-fresh." A carcass was considered fresh if it had at least one clear eye, relatively firm body texture or pink gills. Data collected from carcasses included: date, location (survey reach, GPS point), sex, spawn status (spawned, un-spawned, and unknown), fork length, and adipose fin status (absent, present, and unknown). Spawn status for females was defined as spawned (abdomen extremely flaccid and very few eggs remaining), un-spawned (abdomen firm and swollen or many eggs remaining), or unknown (indeterminable spawn status, usually due to predation on the carcass). The spawn status for males was always categorized as unknown. Adipose fin status was categorized as either "absent", indicating the adipose fin was missing from the salmon due to removal prior to being released from the hatchery , "present", indicating the adipose fin was intact on the carcass, or "unknown", which typically resulted when a carcass was either very deteriorated or had been subject to predation. The head was collected from salmon with an adipose fin status of absent or unknown. Collected heads were transported to the Red Bluff Fish and Wildlife Office (RBFWO) and subsequently processed for CWT recovery as described in U.S. Fish and Wildlife Service (2005). Carcasses of unknown fin status were subsequently reclassified as "absent" if a CWT was recovered from the head or "present" if no CWT was recovered. A small piece of fin tissue, for genetic run determination, and a patch of scales for age-class determination were collected from carcasses. Fin tissues were preserved in 100% ethanol and archived in the USFWS salmonid tissue archive at the RBFWO. Scale patches were air dried prior to being transferred to the CDFW Central Valley scale ageing project. After data were recorded and samples collected, carcasses were cut in half with a machete to prevent resampling and returned to the river.

Data Analysis

The process for removing and decoding CWTs in recovered salmon is described in U.S. Fish and Wildlife Service (2005). For the CWTs that were recovered, age, hatchery of origin, release group size, and release location were determined by querying the tag code in the Regional Mark Information System (RMIS; www.rmpc.org). The age of CWT salmon was determined by identifying brood year relative to return year. Spatial distribution and sex composition were compared between natural-origin and hatchery-origin carcasses.

An expansion factor was calculated for each CWT group and the total number of salmon represented by that CWT code was estimated by dividing the number of salmon recovered with that CWT code by the expansion factor.

$$Expansion\ Factor = \frac{number\ of\ marked\ and\ tagged\ juvenile\ salmon\ in\ a\ CWT\ group}{total\ marked\ and\ unmarked\ juvenile\ salmon\ represented\ by\ the\ CWT\ group}$$

For example, if a CWT is recovered from a group of salmon that had a 25% mark rate, then the expansion factor for this particular CWT would be 0.25, and the expanded number for each

salmon recovered would be 4. In this case, each CWT recovery represents four hatchery-origin salmon, including one marked salmon and three unmarked salmon. Based on these expanded numbers, hatchery-origin contribution percentages were calculated. Application of CWT expansions assumed that a recovered marked salmon represented three additional unmarked salmon with similar biological data and distribution (e.g. sex, hatchery of origin, age, and survey reach). Assumptions were not applied to recovery date, fork length, or distribution based on river mile due to a small sample size for each of these metrics.

To provide a broader perspective of monitoring results in the context of natural spawning FCS in the upper Sacramento River, some data from this USFWS supplemental survey were combined with data collected that were by the California Department of Fish and Wildlife (CDFW) in the uppermost 26 miles of the Sacramento River accessible to anadromous fish. Considered together, these two surveys characterize FCS spawners across the uppermost 74 miles of the Sacramento River, an area that supports a majority of FCS spawners in the mainstem Sacramento River (CDFG 2012).

Results

River Conditions

During the survey period the average flow on the Sacramento River at Bend, California was 7,611 cubic feet per second (cfs). The minimum flow during the survey period was 6,290 cfs on 19 December 2011 and the maximum of 9,610 cfs occurred on 24 November 2011 (Figure 2; http://cdec.water.ca.gov). The average temperature was 10.8 degrees Celsius (°C), with a minimum of 8.2 °C on 14 December 2011 and a maximum of 13.5 °C on 17 October 2011 (Figure 3; http://cdec.water.ca.gov).

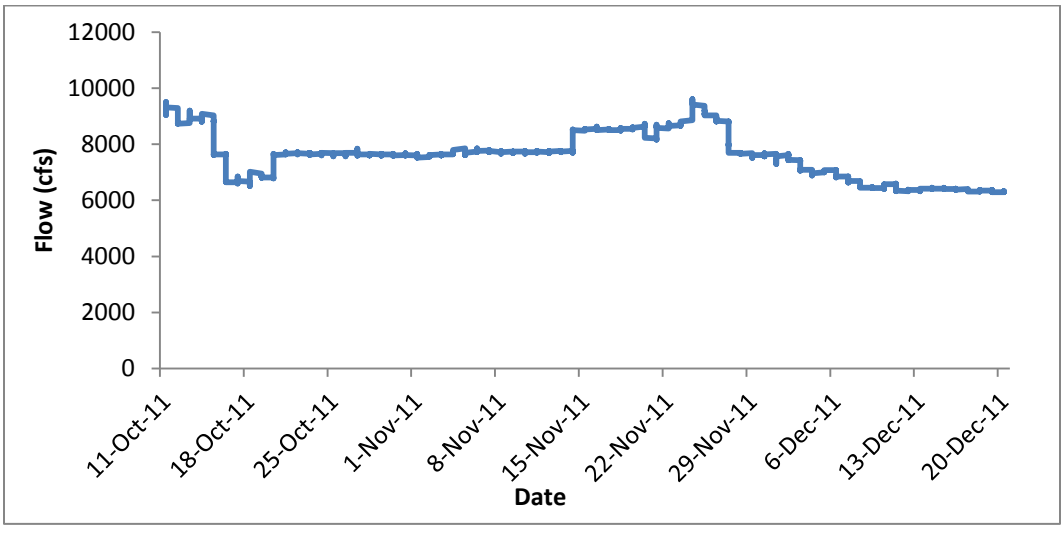


Figure 2. Hourly flow of the Sacramento River at Bend, California from 11 October 2011 through 20 December 2011 (BND, www.cdec.water.ca.gov).

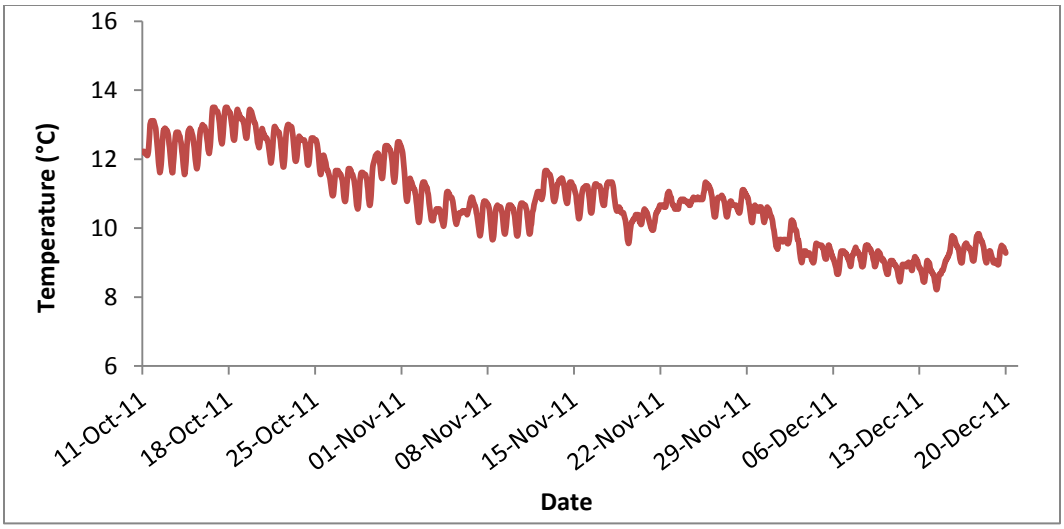


Figure 3. Hourly water temperature of the Sacramento River at Bend, California from 11 October 2011 through 20 December 2011 (BND, www.cdec.water.ca.gov).

Carcass Recoveries

We observed 148 carcasses during the survey period, including 56 fresh carcasses, 51 non-fresh carcasses, and 41 intact skeletons. One-hundred three samples of fin tissue and 76 scale patches were collected. Biological data including, fork length, sex, and spawn condition, was recorded for 107 carcasses. All data and percentages presented are based on the 107 carcasses with associated biological data unless otherwise noted.

CWT Recoveries

The heads were collected from 24 salmon carcasses, including 20 from salmon with an absent adipose fin and 4 from salmon that had unknown adipose fin status. A CWT was recovered from 19 of the heads collected. Tags were not detected in 5 heads (2 absent adipose fin and 3 unknown adipose fin status). One of the 4 heads collected from carcasses with unknown adipose fin status contained a CWT. The 3 carcasses with an unknown adipose fin status from which no CWTs were recovered were reclassified as "present" adipose fin status for subsequent analyses. Two adipose fin-clipped carcasses were recovered that were missing the head either due to depredation (otters or scavengers), or in a highly degraded state. These two carcasses, along with the 2 absent adipose fin carcasses without a CWT, were categorized as "No CWT" and grouped with hatchery-origin salmon for subsequent analyses.

Hatchery-origin Returns

A total of 23 salmon of hatchery-origin were observed, including 19 from which a CWT was recovered and four from which no CWT was recovered. Application of the expansion factors to the 23 hatchery-origin salmon to account for unmarked hatchery production yields an estimate that 80 of the 107 salmon recovered in the survey area were hatchery-origin, representing 74.8% of recovered carcasses. Hatchery-origin carcasses categorized as "No CWT" were given an assumed expansion factor of 0.25 because most FCS were marked at Central Valley fish hatcheries at a 25% rate, and a vast majority of recovered CWTs were from FCS. Hybrid Chinook salmon (e.g., FCS x spring Chinook salmon), spring Chinook salmon, and some experimental release groups of FCS, are marked at a 100% rate.

Coded wire tag recoveries were classified as: Coleman NFH FCS onsite releases (N = 12 recovered, N = 48 expanded), Feather River Hatchery FCS offsite (San Pablo Bay) releases (N = 3 recovered, N = 12 expanded), Feather River Hatchery spring Chinook salmon offsite (San Pablo Bay) releases (N = 1 recovered, N = 1 expanded), Feather River hybrid Chinook salmon offsite (San Pablo Bay) releases (N = 1 recovered, N = 1 expanded), Mokelumne River Hatchery FCS offsite (San Pablo Bay) releases (N = 2 recovered, N = 2 expanded), or no CWT (N = 4, expanded N = 16). Natural-origin salmon (N = 27) comprised 25.2% of the population (Figure 4). No late-fall Chinook salmon were recovered. Eighty-four percent of the recovered males were of hatchery-origin and 55.9% of the recovered females were of hatchery origin.

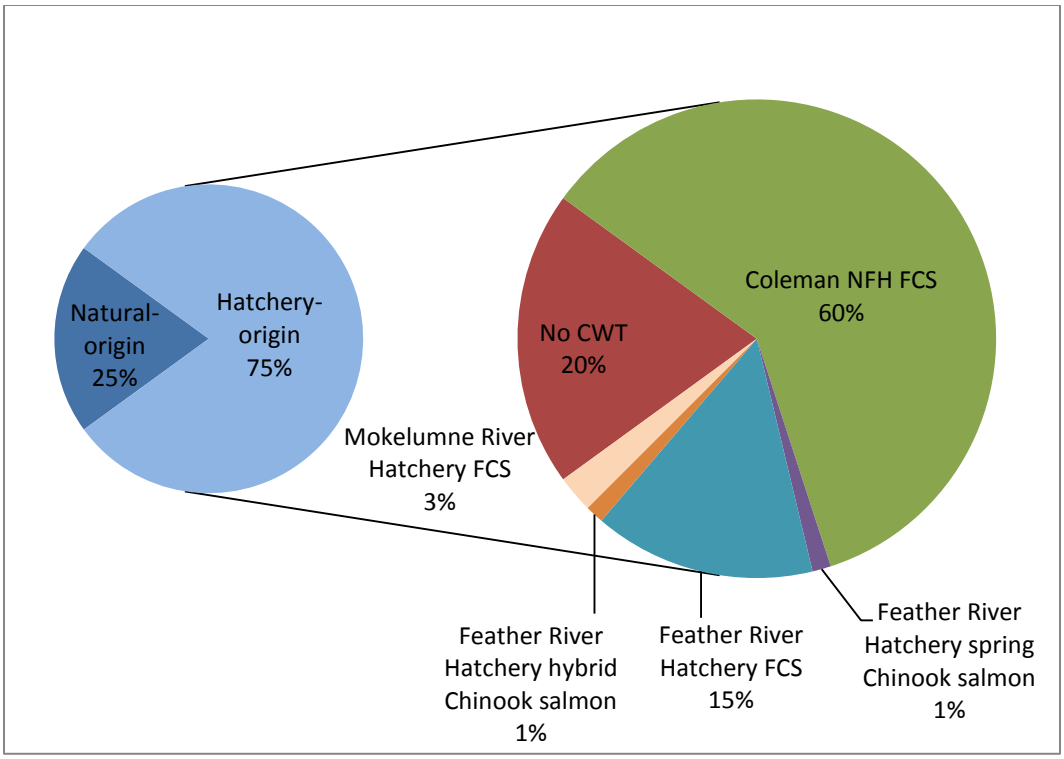


Figure 4. Hatchery contributions to 2011 fall Chinook salmon carcass recoveries on the Sacramento River (RM 229- RM 276) based on expanded CWT recoveries

Temporal and Spatial Distribution

A total of 56 fresh carcasses were recovered with the peak fresh carcass recovery occurring during the week of 13 November 2011. Seventy three percent of fresh females and 88% of fresh males were recovered before or during this week (Figure 5). Only 3 fresh carcasses were found after 30 November 2011, through the last survey on 20 December 2011.

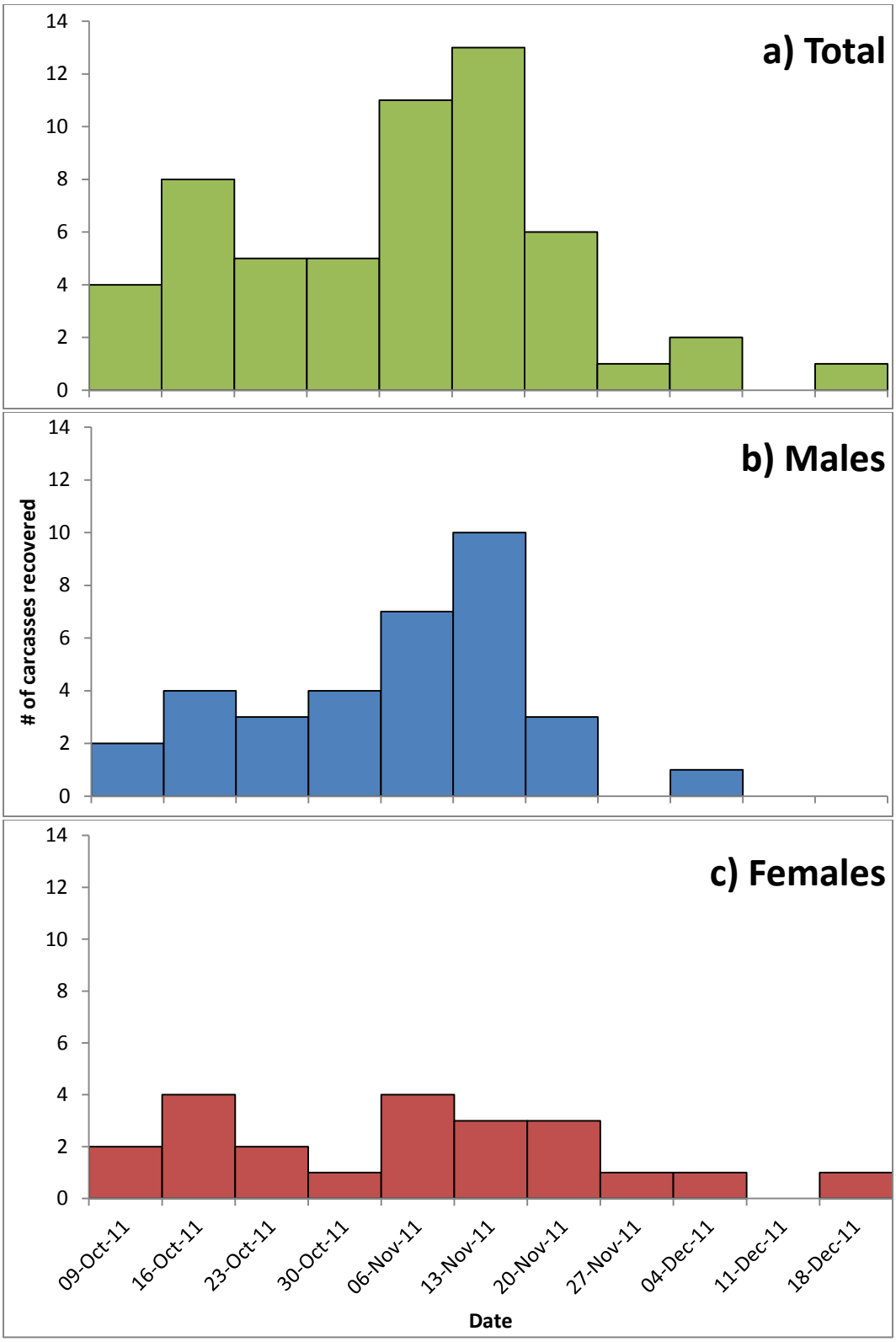


Figure 5. Weekly number of fresh fall Chinook salmon carcasses recovered in the Sacramento River (RM 229- RM 276), a) total number of fresh carcasses, b) number of fresh male carcasses, c) number of fresh female carcasses.

Carcasses were recovered throughout the entire survey area. The spatial distributions of recovered carcasses showed that the highest number of carcass recoveries was in RM 267- RM 269, with about 22% of carcasses recovered in this 3 mile stretch (Figure 6). This area is located downstream of the confluence with Battle Creek (RM 271), where the Coleman NFH is located (Figure 7).

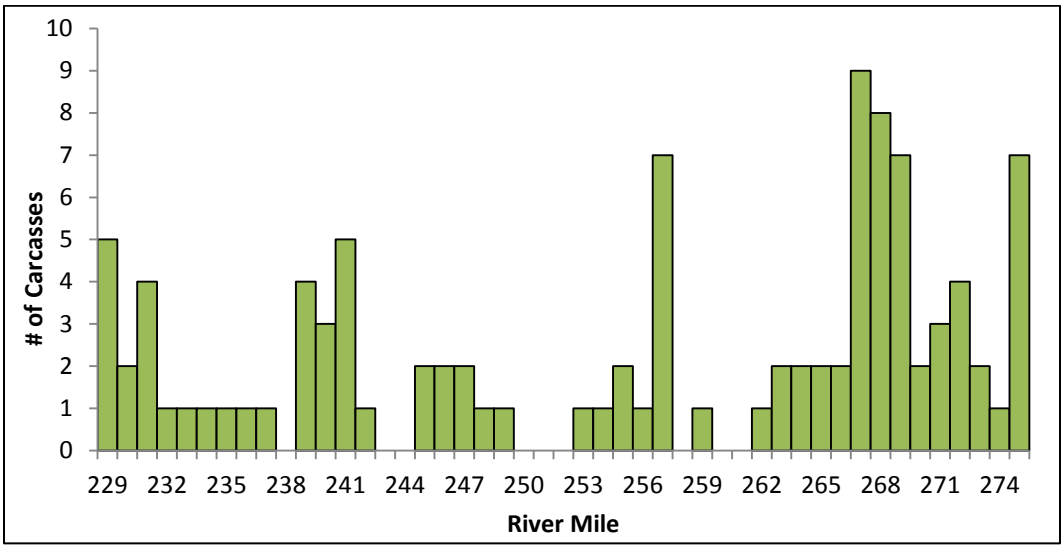


Figure 6. Fall Chinook salmon carcass distribution by river mile on the Sacramento River (RM 229- RM 276) during USFWS supplemental carcass survey in fall 2011.

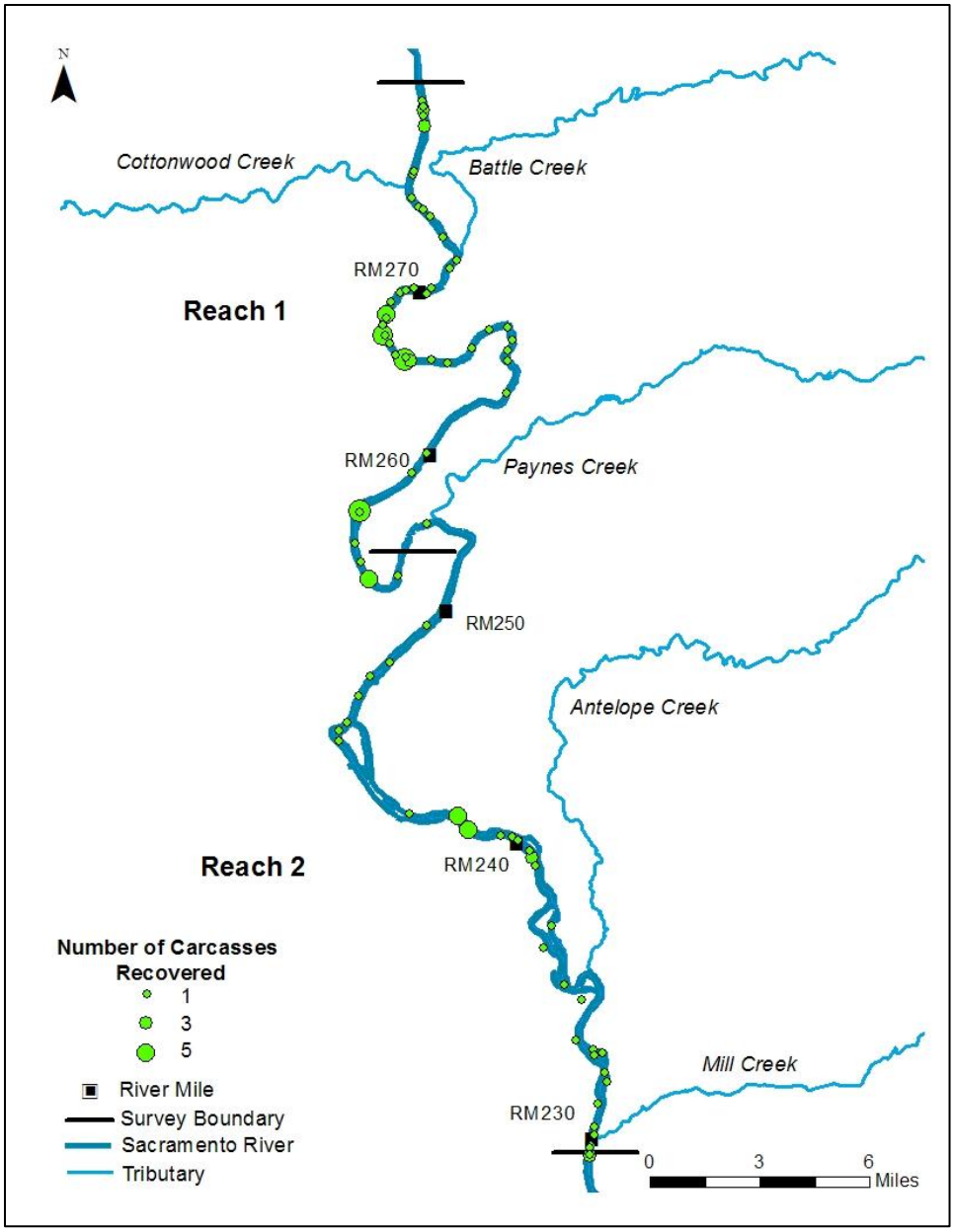


Figure 7. Spatial distribution and abundance of Chinook salmon carcasses recovered on the upper Sacramento River (RM 229- RM 276), California, during fall 2011.

During the survey, 73 male carcasses and 34 female carcasses were recovered. Males outnumbered females at a ratio of 2:1 overall. The male to female ratio of hatchery-origin salmon was approximately 3:1, whereas the ratio for natural-origin males to females was approximately 1:1. Data collected in upstream sections by DFG showed that the male to female ratio was approximately 1:2, regardless of origin (Killam 2012.).

Spatial distribution of male and female carcasses differed across a broad area of the upper Sacramento River. To illustrate the distribution of male and female carcasses throughout a 74 mile stretch of the upper Sacramento River, data from this survey was combined with data from FCS surveys performed by CDFW. Survey reaches are defined by the CDFW as follows: DFG 1

(RM 302- RM 298), DFG 2 (RM 298- RM 296), DFG 3 (RM 296- RM 289), and DFG 4 (RM 289- RM 276); (Killam 2012.).

The percentage of total carcasses that were male consistently decreased in survey reaches further upstream, decreasing from 71% in the lowest survey reach to only 20% in the uppermost reach. The opposite relationship was true for females, which showed a steady increase in the proportion of females for survey reaches further upstream (Figure 8).

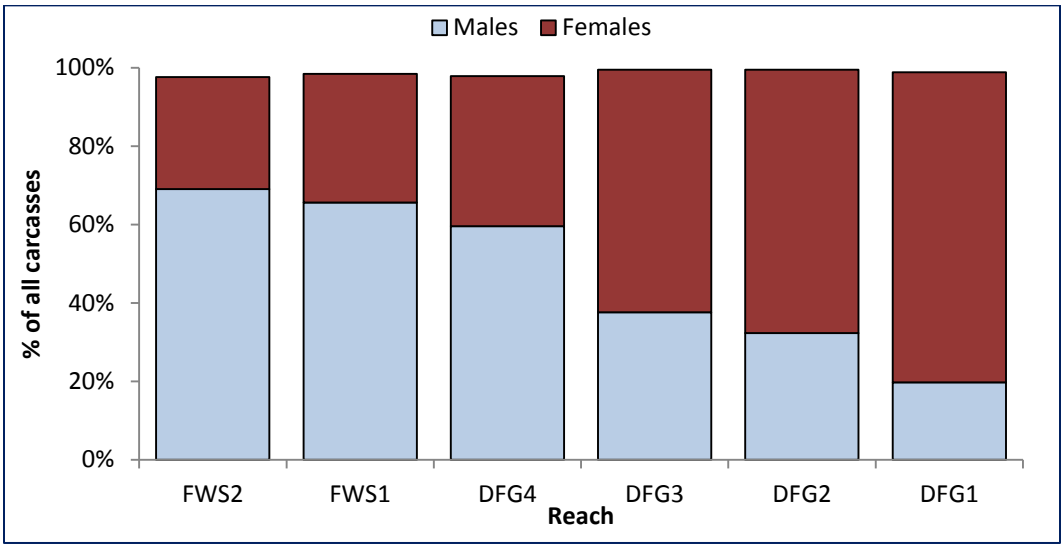
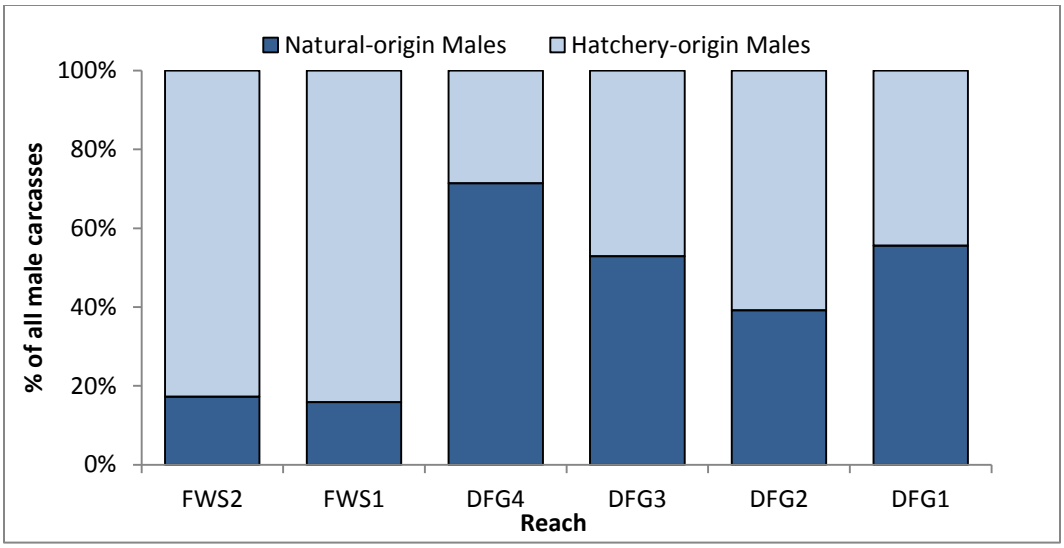


Figure 8. Percent of all recovered fall Chinook salmon carcasses on the upper Sacramento River (RM 229- RM 302) during fall 2011 by sex. Reaches are defined as follows: DFG 1 (RM 302- RM 298), DFG 2 (RM 298- RM 296), DFG 3 (RM 296- RM 289), and DFG 4 (RM 289- RM 276), FWS 1 (RM 276- RM 254) and FWS 2 (RM 254- RM 229).

Spatial distribution hatchery- and natural-origin carcasses differed across a broad area of the upper Sacramento River. Natural-origin carcasses generally represented a larger percentage of recoveries in the upstream survey reaches (DFG 1 through DFG 4) compared to the two reaches (FWS1 and FWS2) furthest downstream (Figure 9). It is important to note that recoveries of carcasses were highest in the DFG 2 and DFG 3 reaches and, therefore, these data are not representative of the entire adult population.

a)



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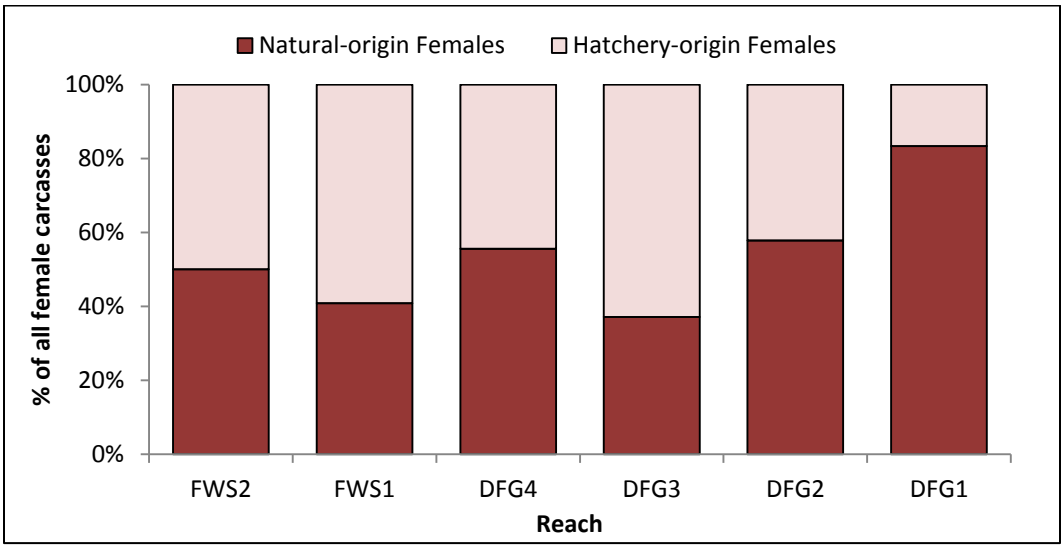

Figure 9. Percent of natural-origin and hatchery-origin fall Chinook salmon carcasses recovered on the Sacramento River (RM 229- RM 302) during fall 2011. a) Percent of male carcasses by origin b) Percent of female carcasses by origin. Percentages shown are in relation to the total number of recoveries in each reach. Reaches are defined as follows: DFG 1 (RM 302- RM 298), DFG 2 (RM 298- RM 296), DFG 3 (RM 296- RM 289), and DFG 4 (RM 289- RM 276), FWS 1 (RM 276- RM 254) and FWS 2 (RM 254- RM 229).

Age Composition and Length-at-Age

Lengths of male carcasses recovered on USFWS supplemental carcass survey were distributed bi-modally with a distinct break from 710 mm to 800 mm occurring between the two modes (Figure 10). This distribution was used to estimate the proportion of grilse (age-2) and adult (age-3 and age-4) males, with larger salmon considered to be adults (49%; N =34) and smaller salmon considered to be grilse (51%; N =35). However, this ratio suggests a lower percentage grilse males than the CWT data from hatchery-origin males. Length distribution for females had a single mode, which likely resulted due to few females returning at age-2. This assumption was supported by the lack of grilse female CWT recoveries (Figure 11). Length was not recorded on four male carcasses, which are excluded from this analysis.

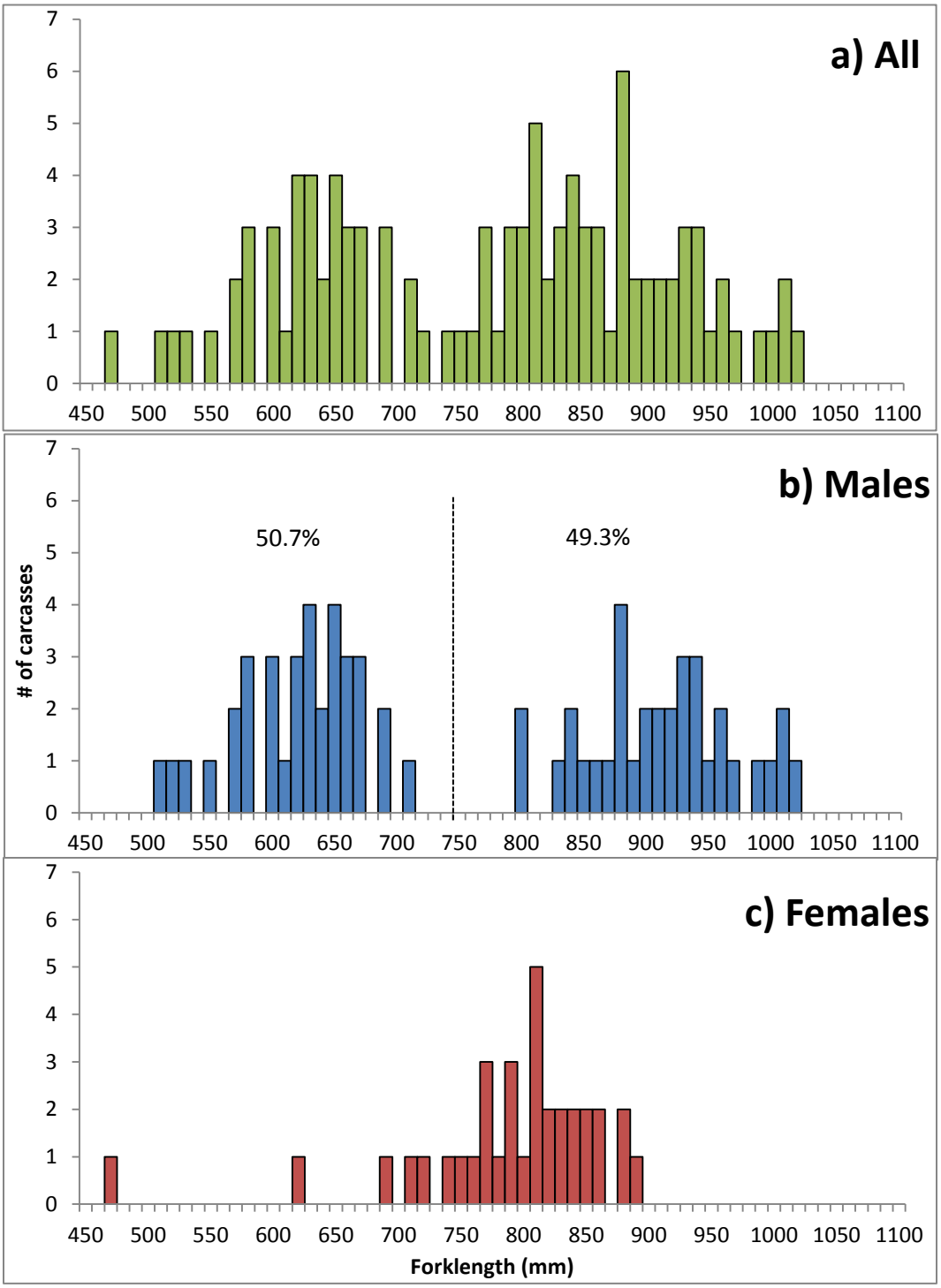

Figure 10. Length frequency distributions of all fall Chinook salmon carcasses recovered on Sacramento River (RM 229- RM 276) during fall 2011. a) All carcasses (N = 103) b) Male carcasses (*N* = 69) c) Female carcasses (*N* = 34). An estimated grilse cutoff was set at >750 mm and is shown as a dotted black line for males. Percentages of salmon above and below this cutoff are shown. A grilse cutoff was not determined for females due to small sample size.

Based on recovered CWTs, 45% of hatchery-origin carcasses were grilse (*N* = 29) and 55% were adult (*N* = 35). All recovered adults were age-3. One hundred percent of hatchery-origin females were adult (*N* = 19), whereas 64 % of hatchery-origin male carcasses were grilse (*N* = 29) and 36% were adults (*N* = 16; Figure 11).

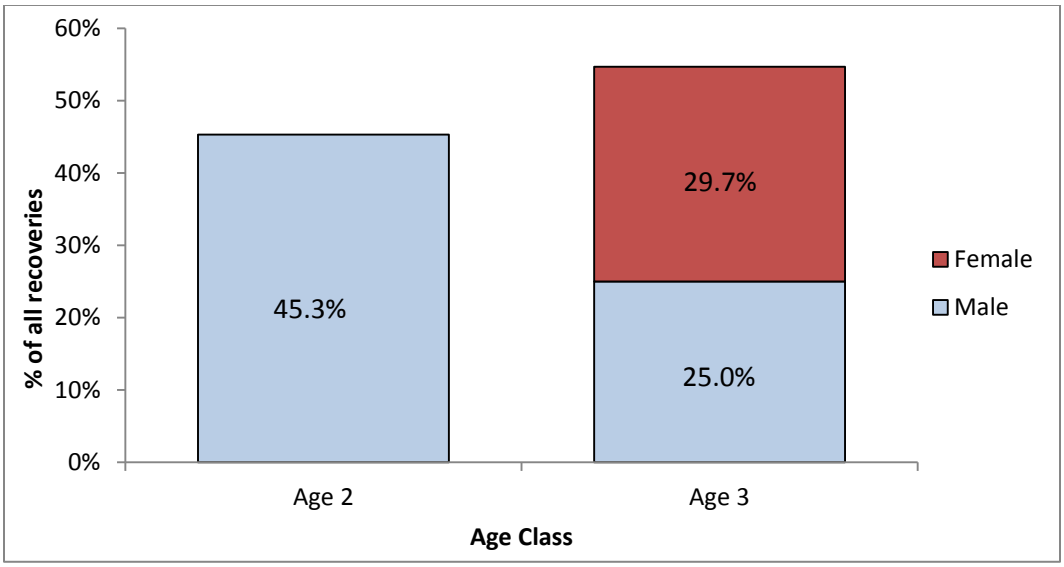

Figure 11. Age of male and female hatchery-origin fall Chinook salmon recovered in the Sacramento River (RM 229- RM 276) during USFWS supplemental carcass survey in fall 2011 based on CWT recoveries.

Discussion

Expansions of CWT recoveries showed that almost 75% of recovered salmon carcasses on surveyed areas of the Sacramento River (RM 229- RM 276) in the fall of 2011 were of hatchery-origin. FCS from Coleman NFH released into Battle Creek comprised the greatest number of hatchery-origin carcass recoveries (60%), followed by Feather River Hatchery FCS (15%), Mokelumne River Hatchery FCS (3%), and Feather River Hatchery spring (1%) and hybrid (1%) run Chinook salmon. It is possible that the high abundance of hatchery-origin Chinook salmon observed in this study was influenced by release practices of juvenile salmon. All Central Valley hatcheries transport some or all juvenile FCS downstream for release, which has been shown to increase survival (Kormos *et al.* 2012). Interestingly, FCS from Coleman NFH off-site releases into San Pablo Bay were not found on this survey, whereas FCS from Coleman NFH on-site releases into Battle Creek comprised the highest percentage of recovered hatchery-origin salmon. These findings are supported by previous assessments of Coleman NFH off-site releases, which showed that juvenile salmon transported and released at distant locations were more likely to stray at geographically distant locations, whereas juvenile salmon released off-site but closer to the hatchery strayed at an intermediate level, and were recovered in closer proximity to the hatchery (Niemela 1996). Therefore, the absence of off-site (San Pablo Bay) released salmon from Coleman NFH should not be assumed to indicate a lower straying rate of those salmon, but rather the salmon may have strayed to more distant locations.

Coleman NFH is located on Battle Creek in Anderson, CA, and the confluence of Battle Creek with the Sacramento River is located at RM 271. The proximate location of Coleman NFH on a

tributary of the upper Sacramento River within the survey area is likely the reason for the high percentage of recovered hatchery-origin carcasses originating from this hatchery relative to other Central Valley hatcheries. Annually, FCS return to Battle Creek, and are either collected at the hatchery or spawn naturally within the creek. In 2011, an estimated 12,513 FCS spawned in Battle Creek (California Department of Fish and Game 2012). While some spawned out males leaving Battle Creek may have ended up within the survey area, it is not likely that this was a significant contribution to the carcass recoveries on this survey. While the peak carcass recovery (RM 267- RM 269) was downstream of the confluence of Battle Creek (RM 271), there were also peaks of recoveries upstream of this section (RM 275), and lower Battle Creek has long sections of slack water that would not easily transport carcasses back into the Sacramento River.

Within the survey area, male carcass recoveries outnumber females at a 2:1 ratio, with the male to female ratio for hatchery-origin recoveries equaling 3:1, and a 1:1 sex ratio in natural-origin salmon. Conversely, a male to female sex ratio of 1:2 was seen in the upper section of the Sacramento River surveyed by CDFW (RM 276- RM 302) (Killam 2012.). It is commonly observed that carcasses of Chinook salmon males are distributed further downstream than those of females (Killam 2009). This can be explained because male Chinook salmon often move downstream after spawning whereas females will typically remain near their redds until they die. As a result of these differing behaviors, carcasses of female Chinook salmon are usually found in closer proximity to spawning areas, whereas males are found downstream of spawning areas. Based on the distribution of male and female carcasses, most FCS natural spawning activity within the upper Sacramento River is likely occurring upstream of the FWS carcass survey reaches (RM 229- RM 276).

Over 80% of male carcasses recovered on this survey were hatchery-origin, whereas females were almost equally hatchery-origin and natural-origin. This difference may be a factor of the abundance of age-2 class hatchery-origin males (45% of all hatchery-origin recoveries), which was also observed in other Sacramento River tributaries in 2011 (Killam and Merrick 2012a, 2012b), or this data might suggest that hatchery-origin males stray at a higher rate than hatchery-origin females. Length frequency data suggests that approximately half of all recovered male carcasses were grilse, whereas CWT recoveries showed 64% grilse males. This difference may be attributed to a higher ratio of grilse to adult returns in hatchery-origin males than natural-origin males. Hatchery-origin Chinook salmon have been shown to mature and return at an earlier age compared to natural-origin salmon, partially attributed to a higher lipid content diet within the hatchery environment, and these fish are predominantly males (Shearer and Swanson 2000, Shearer *et al*. 2000; Shearer *et al.* 2002; Larsen *et al*. 2004).

CDFW carcass surveys in the upper river recovered 47% hatchery-origin returns, with similar ratios of hatchery- to natural-origin in both sexes and a 1:2 male to female ratio (Killam 2012). A majority of these hatchery-origin recoveries were Coleman NFH FCS onsite releases (37%) followed by Feather River Hatchery FCS offsite releases (34%), and Coleman NFH FCS offsite releases (7%). Other recovered CWT included Mokelumne River Hatchery FCS offsite releases, Merced River Hatchery FCS offsite releases, and Feather River Hatchery spring run and hybrid run offsite releases which each represented less than 5% of CWT recoveries.

This compositional difference observed across FCS spawning areas of the upper Sacramento River highlights the importance of surveying across broad geographic areas for a more complete representation of the FCS escapement in the upper Sacramento River. Information generated in this survey improves our understanding of FCS run composition, including spatial and temporal distributions, sex ratio and age class structure of recovered carcasses, and straying by hatchery-origin salmon, in addition to supplementing data collected on CDFW surveys. Continuing to monitor escapement of hatchery-origin salmon will enable better management of both hatchery- and natural-origin populations.

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Appendix I

Table A. 1. Release information associated with coded wire tags recovered from Chinook salmon carcasses in Sacramento River during fall 2011. Numbers of juvenile salmon released are categorized based on juvenile retention data as follows: Clip/Tag = adipose fin-clipped with coded wire tag; No Clip/Tag = no adipose fin-clip with coded wire tag; Clip/ No Tag = adipose fin-clipped without coded wire tag; No Clip/ No Tag = no adipose fin-clip without coded wire tag.

CWT Code	Hatchery of Origin	Run	Release Location	Brood Year	Clip/ Tag	No Clip/ Tag	Clip/ No Tag	No Clip/ No Tag	Expansion Factor	Number Recovered	Expanded Number
055181	Coleman NFH	Fall	Coleman NFH	2009	95007	0	244	286921	0.249	1	4.02
055183	Coleman NFH	Fall	Coleman NFH	2009	116291	282	0	349904	0.249	1	4.02
055185	Coleman NFH	Fall	Coleman NFH	2009	108389	0	0	325252	0.250	1	4.00
055186	Coleman NFH	Fall	Coleman NFH	2009	105794	0	0	317531	0.250	1	4.00
055195	Coleman NFH	Fall	Coleman NFH	2009	112693	788	1182	347451	0.244	1	4.10
055223	Coleman NFH	Fall	Coleman NFH	2009	101711	0	0	305381	0.250	2	8.00
054894	Coleman NFH	Fall	Coleman NFH	2008	114907	0	0	344836	0.250	1	4.00
054895	Coleman NFH	Fall	Coleman NFH	2008	124228	0	0	372882	0.250	1	4.00
054896	Coleman NFH	Fall	Coleman NFH	2008	112556	0	0	338978	0.249	1	4.02
054897	Coleman NFH	Fall	Coleman NFH	2008	125703	0	0	377299	0.250	1	4.00
054899	Coleman NFH	Fall	Coleman NFH	2008	111839	0	0	336830	0.249	1	4.02
068606	Feather River Hatchery	Fall	San Pablo Bay Net Pens	2008	393802	0	1417	1192256	0.248	1	4.03
068635	Feather River Hatchery	Fall	San Pablo Bay Net Pens	2008	397598	0	5282	1210589	0.246	1	4.07
068636	Feather River Hatchery	Fall	San Pablo Bay Net Pens	2008	398538	0	4117	1210837	0.247	1	4.05
062589	Feather River Hatchery	Hybrid	Tiburon Net Pens	2008	13010	0	334	334	0.951	1	1.05
068039	Feather River Hatchery	Spring	San Pablo Bay Net Pens	2009	109615	0	5649	0	0.951	1	1.05
068656	Mokelumne River Hatchery	Fall	Sherman Island	2008	71587	0	79	0	0.999	2	2.00
No CWT	--	--	--	--	--	--	--	--	*0.250*	4	16.00
Total										23	80

Table A. 2. Biological data from Chinook salmon carcasses with a coded wire tag in the Sacramento River (RM 229- RM 276) during fall 2011. " NTD" indicates there was no coded wire tag detected in the head, and "No Head" designates an adipose fin-clipped carcass for which no head was recovered, due to predation or deteriorated physical condition. One coded wire tag was lost prior to decoding. A sample number "0" indicates a tissue was not collected for the carcass, due to deteriorated physical condition.

Date	Sample	Sex	Fork length	Adipose Fin Status	Spawn Condition	Carcass Condition	Reach	CWT Code
10/11/2011	1751	Female	690	Absent	Spawned	Fresh	2	062589
10/12/2011	1752	Male	1020	Unknown	Unknown	Fresh	1	NTD
10/12/2011	1753	Male	580	Absent	Unknown	Non-Fresh	1	068039
10/12/2011	1754	Female	860	Present	Unspawned	Fresh	1	
10/12/2011	1755	Male	920	Present	Unknown	Fresh	1	
10/12/2011	0	Male	0	Present	Unknown	Non-Fresh	1	
10/17/2011	1756	Female	824	Present	Unspawned	Non-Fresh	2	
10/18/2011	1758	Male	840	Unknown	Unknown	Fresh	1	055185
10/18/2011	1765	Female	810	Absent	Spawned	Non-Fresh	1	068635
10/18/2011	1764	Male	640	Present	Unknown	Fresh	1	
10/18/2011	1763	Male	650	Present	Unknown	Fresh	1	
10/18/2011	1762	Female	750	Absent	Spawned	Fresh	1	068606
10/18/2011	1761	Female	790	Present	Unspawned	Fresh	1	
10/18/2011	0	Male	0	Present	Unknown	Non-Fresh	1	
10/18/2011	1759	Female	840	Present	Unspawned	Fresh	1	
10/18/2011	1760	Female	820	Present	Unspawned	Fresh	1	
10/18/2011	1757	Male	940	Unknown	Unknown	Fresh	1	NTD
10/24/2011	1768	Male	620	Present	Unknown	Fresh	2	
10/24/2011	1767	Female	770	Present	Unknown	Fresh	2	
10/24/2011	1766	Male	660	Present	Unknown	Fresh	2	
10/25/2011	1771	Male	900	Present	Unknown	Fresh	1	
10/25/2011	1770	Female	880	Present	Spawned	Fresh	1	
10/25/2011	1769	Female	840	Present	Unspawned	Non-Fresh	1	
10/31/2011	0	Male	0	Present	Unknown	Non-Fresh	2	
10/31/2011	1776	Male	650	Present	Unknown	Fresh	2	
10/31/2011	1778	Male	990	Present	Unknown	Non-Fresh	2	
10/31/2011	1777	Male	600	Absent	Unknown	Fresh	2	
10/31/2011	1772	Female	470	Present	Spawned	Fresh	2	
10/31/2011	1775	Male	850	Absent	Unknown	Non-Fresh	2	054896
10/31/2011	1773	Male	880	Absent	Unknown	Non-Fresh	2	054895
10/31/2011	1774	Male	660	Present	Unknown	Non-Fresh	2	
10/31/2011	1779	Male	800	Present	Unknown	Fresh	2	
10/31/2011	0	Male	0	Present	Unknown	Non-Fresh	2	
11/1/2011	1782	Male	568	Absent	Unknown	Non-Fresh	1	055183
11/1/2011	1784	Male	625	Present	Unknown	Non-Fresh	1	
11/1/2011	1783	Male	630	Present	Unknown	Fresh	1	
11/1/2011	1781	Male	925	Present	Unknown	Non-Fresh	1	
11/1/2011	1780	Male	595	Present	Unknown	Non-Fresh	1	

Date	Sample	Sex	Fork length	Adipose Fin Status	Spawn Condition	Carcass Condition	Reach	CWT Code
11/7/2011	1795	Male	859	Present	Unknown	Fresh	2	
11/7/2011	1794	Male	825	Present	Unknown	Fresh	2	
11/7/2011	1793	Female	805	Present	Spawned	Non-Fresh	2	
11/7/2011	1790	Male	1005	Present	Unknown	Non-Fresh	2	
11/7/2011	1791	Male	904	Present	Unknown	Fresh	2	
11/7/2011	1785	Male	550	Absent	Unknown	Fresh	2	055223
11/7/2011	1786	Male	1000	Present	Unknown	Non-Fresh	2	
11/7/2011	1787	Female	880	Present	Spawned	Fresh	2	
11/7/2011	1788	Female	770	Absent	Spawned	Fresh	2	068636
11/7/2011	1789	Male	580	Present	Unknown	Fresh	2	
11/7/2011	1792	Male	634	Absent	Unknown	Fresh	2	055181
11/8/2011	1796	Female	710	Present	Spawned	Non-Fresh	1	
11/8/2011	1797	Female	760	Present	Spawned	Fresh	1	
11/8/2011	1798	Female	720	Present	Spawned	Fresh	1	
11/8/2011	1799	Male	690	Absent	Unknown	Non-Fresh	1	
11/8/2011	1800	Male	670	Absent	Unknown	Fresh	1	055195
11/14/2011	1803	Male	650	Present	Unknown	Non-Fresh	2	
11/14/2011	1809	Female	830	Present	Spawned	Non-Fresh	2	
11/14/2011	1808	Male	900	Present	Unknown	Fresh	2	
11/14/2011	1807	Male	600	Present	Unknown	Fresh	2	
11/14/2011	1806	Male	880	Present	Unknown	Non-Fresh	2	
11/14/2011	1804	Male	620	Absent	Unknown	Non-Fresh	2	NTD
11/14/2011	1802	Male	840	Present	Unknown	Non-Fresh	2	
11/14/2011	1801	Male	690	Present	Unknown	Fresh	2	
11/14/2011	1805	Male	650	Present	Unknown	Non-Fresh	2	
11/15/2011	1839	Male	670	Present	Unknown	Non-Fresh	1	
11/15/2011	1818	Male	950	Present	Unknown	Non-Fresh	1	
11/15/2011	1810	Male	610	Present	Unknown	Non-Fresh	1	
11/15/2011	1811	Female	810	Present	Spawned	Fresh	1	
11/15/2011	1812	Male	870	Present	Unknown	Non-Fresh	1	
11/15/2011	1813	Male	670	Absent	Unknown	Non-Fresh	1	055186
11/15/2011	1814	Female	790	Present	Spawned	Fresh	1	
11/15/2011	1815	Male	930	Absent	Unknown	Non-Fresh	1	054899
11/15/2011	1816	Male	890	Present	Unknown	Fresh	1	
11/15/2011	1817	Male	625	Present	Unknown	Fresh	1	
11/15/2011	1836	Male	530	Present	Unknown	Non-Fresh	1	
11/15/2011	1837	Male	880	Present	Unknown	Non-Fresh	1	
11/15/2011	1819	Male	565	Present	Unknown	Non-Fresh	1	
11/15/2011	1835	Male	970	Unknown	Unknown	Fresh	1	NTD
11/15/2011	1834	Female	770	Present	Spawned	Fresh	1	
11/15/2011	1833	Male	1010	Present	Unknown	Non-Fresh	1	
11/15/2011	1832	Male	920	Absent	Unknown	Fresh	1	054897
11/15/2011	1831	Male	510	Present	Unknown	Non-Fresh	1	

Date	Sample	Sex	Fork length	Adipose Fin Status	Spawn Condition	Carcass Condition	Reach	CWT Code
11/15/2011	1829	Male	520	Absent	Unknown	Non-Fresh	1	055223
11/15/2011	1827	Male	940	Present	Unknown	Non-Fresh	1	
11/15/2011	1826	Female	860	Present	Spawned	Non-Fresh	1	
11/15/2011	1825	Male	940	Present	Unknown	Fresh	1	
11/15/2011	1824	Female	805	Present	Spawned	Non-Fresh	1	
11/15/2011	1823	Male	660	Present	Unknown	Fresh	1	
11/15/2011	1822	Female	740	Present	Spawned	Non-Fresh	1	
11/15/2011	1821	Male	620	Present	Unknown	Fresh	1	
11/15/2011	1820	Male	710	Present	Unknown	Non-Fresh	1	
11/15/2011	1828	Male	960	Present	Unknown	Non-Fresh	1	
11/15/2011	1838	Female	820	Present	Spawned	Non-Fresh	1	
11/21/2011	1843	Male	930	Present	Unknown	Fresh	2	
11/21/2011	1842	Female	850	Present	Spawned	Non-Fresh	2	
11/21/2011	1841	Male	880	Present	Unknown	Fresh	2	
11/21/2011	1840	Female	620	Present	Spawned	Fresh	2	
11/22/2011	1845	Female	800	Absent	Spawned	Fresh	1	068656
11/22/2011	1846	Female	850	Present	Spawned	Fresh	1	
11/22/2011	1844	Female	780	Absent	Spawned	Non-Fresh	1	054894
11/22/2011	1847	Male	800	Present	Unknown	Fresh	1	
11/29/2011	1848	Male	580	Absent	Unknown	Non-Fresh	1	NTD
11/29/2011	1849	Female	790	Present	Spawned	Fresh	1	
11/29/2011	1850	Male	630	Present	Unknown	Non-Fresh	1	
12/5/2011	1915	Female	804	Absent	Spawned	Fresh	2	068656
12/6/2011	1916	Male	960	Present	Unknown	Non-Fresh	1	
12/6/2011	1917	Male	910	Present	Unknown	Fresh	1	
12/19/2011	1918	Female	890	Present	Spawned	Fresh	2	

Table A. 3. Hatchery releases of fall, spring and hybrid Chinook salmon in the Central Valley for brood years 2007, 2008, and 2009. These are release summaries age-2, age-3 and age-4 salmon in 2011 from hatcheries in California's Central Valley (Coleman National Fish Hatchery (NFH), Feather River Fish Hatchery and the Feather River Hatchery Annex, Nimbus Fish Hatchery, Mokelumne River Fish Hatchery, and Merced River Fish Hatchery). This is a summary of likely fish that may have been encountered during the survey. Data was obtained from the Regional Mark Information System (RMIS) database (www.rmpc.org).

Hatchery	Run	Release Location	Brood Year	# Released	# CWT Recovered	Expanded #
Coleman National Fish Hatchery	Fall	Coleman NFH	2007	11232501	-	-
			2008	12529458	5	20
			2009	10210147	7	28
		Sacramento River Colusa To Red Bluff Diversion Dam	2007	811571	-	-
			2008	368609	-	-
			2009	484432	-	-
		Mare Island at Minor Point	2008	1059183	-	-
			2009	874800	-	-
		Sacramento River at Clarksburg	2007	99244	-	-
		Sacramento River at Red Bluff Diversion Dam	2007	101881	-	-
		San Pablo Bay Net Pens	2007	455378	-	-
Feather River Fish Hatchery	Fall	San Pablo Bay Net Pens	2007	6414782	-	-
			2008	7013128	3	12
			2009	7411675	-	-
		Wickland Oil Net Pen	2007	1041669	-	-
			2008	180004	-	-
			2009	2124375	-	-
		Mare Island Net Pen	2007	1966070	-	-
			2008	373241	-	-
		Tiburon Net Pens	2008	78123	-	-
			2009	41873	-	-
		Benicia	2007	102225	-	-
		Mokelumne River at Lighthouse Marina	2007	107788	-	-
		Sacramento River at Isleton	2007	109412	-	-
		Sacramento River at West Sacramento	2007	186568	-	-
		Sacramento River at Elkhorn Boat Ramp	2007	219799	-	-
		Santa Cruz Harbor Net Pen	2009	122334	-	-
	Hybrid	Benicia	2008	56212	-	-
		Mare Island Net Pen	2008	194794	-	-
		Sacramento River at Discovery Park	2008	52329	-	-
		Sacramento River at Garcia Bend	2008	107696	-	-
		Sacramento River At Miller Park	2008	44422	-	-
		Sacramento River at Pittsburg	2008	96224	-	-
		Sacramento River at West Sacramento	2008	89534	-	-
		Sacramento River at Elkhorn Boat Ramp	2008	51924	-	-
		Tiburon Net Pens	2008	13678	1	1
	Spring	Feather River at Boyds Pump Ramp	2007	1414343	-	-
			2008	1016835	-	-
			2009	1040645	-	-
		San Pablo Bay Net Pens	2007	1153734	-	-
			2008	1007177	-	-
			2009	1085409	1	1
		Wickland Oil Net Pen	2007	118027	-	-

Hatchery	Run	Release Location	Brood Year	# Released	# CWT Recovered	Expanded #
Mokelumne River Fish Hatchery	Fall	Mokelumne River at New Hope Landing	2007	406593	-	-
		San Pablo Bay Net Pens	2007	4188645	-	-
		Tiburon Net Pens	2007	51600	-	-
		San Joaquin River Sherman Island Opposite Jersey Point	2008	250969	2	2
		Mokelumne River Fish Installation Weir	2009	99157	-	-
		San Joaquin Sherman Island Net Pen	2009	2023958	-	-
Merced River Fish Hatchery	Fall	San Joaquin River at Jersey Point	2008	34532	-	-
			2009	165213	-	-
Nimbus Fish Hatchery	Fall	Mare Island Net Pen	2008	3924887	-	-
			2009	1391632	-	-
		San Pablo Bay Net Pens	2007	4894507	-	-
		American River	2008	270000	-	-
		Sacramento River At Discovery Park	2009	2946623	-	-
		American River At Sunrise	2009	274514	-	-
Grand Total				94,186,083	19	64